# LOW-THERMAL-MASS KILN INSTALLATION at PACIFIC CLAY PRODUCTS, INC.

## Analysis of Business, Environmental, and Energy Issues


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Contract Number: 400-96-019
Work Authorization: 99-12

**Supported by U.S. Department of Energy**
NICE$^3$ Grant
Office of Industrial Technology
http://www.oit.doe.gov/nice3


**August 31, 1999**

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# 1. Executive Summary

## *Overview*

In 1996, Pacific Clay Products, Inc. commissioned a new production line at the Alberhill Plant in Lake Elsinore, California. The facility was expanded to increase plant production, reduce operating costs, and take advantage of new kiln technology developed since the company's original tunnel kilns went online in the 1950s. The new kiln was built in addition to Pacific Clay's existing tunnel kilns, which remained in place.

After examining various options, Pacific Clay chose a modern low-thermal-mass (LTM) tunnel kiln that offers numerous benefits over traditional high-thermal-mass kilns and could address the production, cost, and efficiency goals set by the company. According to projections, the LTM kiln had the potential to reduce cycle time from 96 hours to 48 hours, double production capacity, and cut energy costs by 50%. It was also expected to reduce production losses due to product variations from about 10% to 1-2%.

Swindell Dressler produced the LTM kiln that was installed at Pacific Clay. This kiln was designed to use existing clay grinding and mixing facilities, but incorporates a new integrated product manufacturing line (e.g., extruders) and automated product-handling equipment. It also uses a new kiln car design that features a wider profile and lower-thermal-mass components than the older cars—characteristics contributing to faster firing times.

Figure 1 and Figure 2 below show the old and new kiln cars, demonstrating the different approach in firing clay products.

**Figure 1: Old Kiln Car**

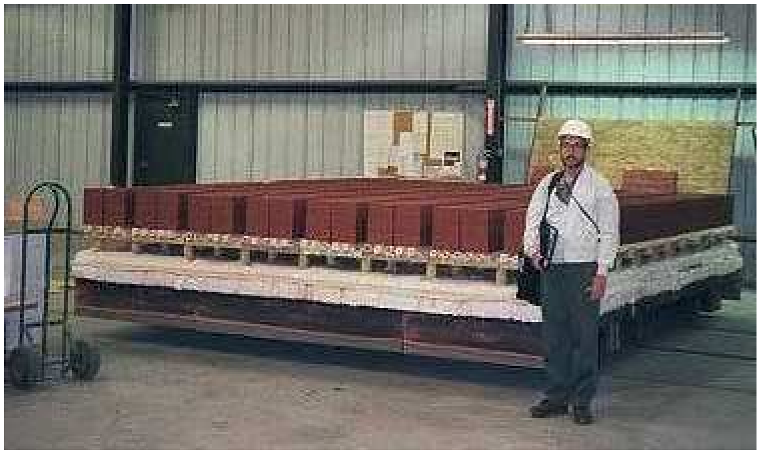

**Figure 2: New Kiln Car**

This report summarizes key results that other kiln owners can leverage to determine applicability of low-thermal-mass kiln technology in their plants. The report includes eight sections:

- *Executive Summary*—describing business and technical issues for decision makers and technical staff, with the business and technical sections each intended to stand alone when used with the overview
- *Case Study Summary*—giving a one-sheet summary intended to stand-alone independently from this report
- *Background*—summarizing reasons for pursing the project
- *Plans and Expectations*—providing an overview of benefits the project was expected to provide
- *Construction and Startup*—describing Pacific Clay's experiences in obtaining permits and installing the new plant
- *Results* —showing the impact on the company's bottom line
- *Potential California Applicability*—briefly describing the market potential for other California installations
- *Appendices* —including technical references and plant performance details

## *Summary of Business Issues*

### Project Cost and Financing

The project was completed at a cost to the company of $7.8 million. Because internal funding was immediately available, financing was not an issue. Therefore, the company did not conduct a financial analysis of return-on-investment payback.

However, anticipating that the new kiln's high efficiency would create substantial environmental benefits—such as reduced $NO_X$ emissions and lower electricity and gas use—Pacific Clay pursued funding assistance from local electric and gas utilities, the local air quality management district, and the California Energy Commission (CEC). Funds were available only from CEC, which provided $385,973.00 through the U.S. Department of Energy's NICE[3] (National Industrial Competitiveness through Energy, Environment, and Economics) program.

The kiln was constructed in 1995–1996 and became operational in April 1996—well ahead of the projected January 1997 deadline. Project costs rose in a few areas during construction. For instance, county zoning regulations required raising the plant two feet and including a fire protection system, adding $500,000 to the original project cost of $7.3 million. Other startup issues, discussed below, further increased costs, but Swindler Dressler absorbed those increases.

## Startup Problems And Solutions

Upon startup, the company faced a number of hurdles. The initial production loss rate was about 35%—far above the 1-2% expected rate. After Swindell Dressler added a 20-foot extension at their expense, the kiln immediately achieved a 2% loss rate. Subsequently, Pacific Clay has experienced periodic higher-than-normal production loss rates, and Swindell Dressler is installing new fans to address the problem.

## New Labor Requirements

Operating the new production line requires a more sophisticated labor force and a longer work week. Specifically, the LTM kiln needs four highly skilled production crews of 7 people each to operate seven days a week, whereas two lesser-skilled production crews of 35-40 people operate one of Pacific Clay's existing brick production lines five days a week. Further, the new crews required about 3 months of extensive training before they could operate the new plant. Finally, supervisory costs are higher with the brick production crews at the new plant working seven days a week, instead of five days a week at the existing plant.

## Projected Versus Actual Operation

As with many new products, actual benefits of the LTM kiln did not always meet expectations, and in some cases are not easily quantified. On the plus side, the new kiln has improved product quality, production capability, and productivity while cutting energy use, which in turn reduced energy costs and environmental emissions.

Labor and maintenance savings are smaller than expected, partly because new firing cycles must be established for new products, and startup problems have delayed achieving some benefits. Further, lack of detailed energy-use metering and corresponding records do not allow direct comparison of some characteristics. Table 1 compares the 1995 baseline performance of the existing kilns with projected and actual operation of the LTM kiln in the first half of 1999.

**Table 1: Summary of New Kiln Performance Characteristics**

| | *Baseline* | *Projected* | *Actual* |
|---|---|---|---|
| Production capacity | 60,000 | 90,000 | 90,000 |
| Production losses | 10% | 2% | 5% |
| Gas cost[1] | $17.51/ton | $8.75/ton | $11.34/ton |
| Labor | 1.3 hr/ton | 0.80 hr/ton | 0.99 hr/ton |
| Maintenance cost[2] | $13/ton | $1/ton | $9.61/ton |

## New Market Opportunities

With reduced operating costs, Pacific Clay is more competitive in markets nationwide, including the East Coast, despite shipping costs.

Further, the LTM kiln's low stacking height has allowed Pacific Clay to increase the range of its production capability. Pacific Clay now manufactures a successful new premium product with about 25% higher market value that does not have the strength to be stacked six feet high in the old kiln

## Future Considerations

For companies considering LTM kiln installations, Pacific Clay recommends adopting a production layout that would use more kiln cars, thus providing a two-day backlog to cover weekend operation. This would cut labor costs by setting brick production on a five-day schedule. (Firing would remain on a seven-day schedule.) In addition, kiln installation costs have increased since the company purchased the LTM kiln. A Pacific Clay vice president estimates that a similar-sized plant would now cost about $11 million, rather than their $7.8 million cost.

## The Bottom Line

The new kiln has created significant benefits for Pacific Clay. As noted above, it has enabled to company to increase production capacity and productivity, improve product quality, produce new products, and cut energy costs. By cutting gas use it also lowered plant $NO_X$ emissions. Companies considering the installation of an LTM kiln should be aware that a reduction of $NO_X$ emissions could allow them to sell $NO_X$ credits.

Although startup problems were greater than expected, Pacific Clay is satisfied with the new LTM kiln and its associated production equipment, and would undertake the project again. In fact, it is considering an LTM kiln for its Yankee Hill Brick and Tile plant in Lincoln, Nebraska.

[1] Gas cost calculated using average 1999 gas rate.
[2] Plant average data, because maintenance costs are not available for individual kilns.

## *Summary of Technical Issues*

### Characteristics and Operation of the Original Tunnel Kilns

Using two 1950-vintage tunnel kilns, tunnel kilns 2 and 3 (TK-2 and TK-3), bricks are manufactured in a continuous process. Bricks are formed and stacked about six feet high on cars with high-refractory characteristics. A drying tunnel brings the moisture content down from about 20% to about 1% in about 48 hours. After drying, the product enters the firing kilns, which operate at about 1900–2300°F, depending on product type. Products are fired for about 48 hours, depending on product type.

In many phases of the production line workers move and stack bricks individually. Variations in product quality require rejecting about 10% of the products fired.

Pacific Clay often operates the plant continuously and production lines are designed to provide a 2.6-day reserve of unfired bricks. Thus the plant has adequate product-forming capacity to produce enough bricks in five days (a normal Monday through Friday work week) to enable the kilns to operate continuously, seven days a week.

With lower production demands operators may shut down kilns for extended periods. Restarting a kiln requires about 4–5 days from a cold start, or 24 hours from an “idle” condition of 500°F. Such a long restart time makes short-term shutdowns impractical.

### Project Timeline

Project design and construction were completed ahead of schedule. However, startup took longer than expected, resulting in TK-4 operating properly about the same time as planned.

**Table 2: Project Timeline**

| *Activity* | *Actual Date* | *Projected Date* |
|---|---|---|
| Design and feasibility begins | July 1995 | July 1995 |
| Construction complete | April 1996 | September 1996 |
| Extend TK-4 | December 1996 | na |
| Proper TK-4 operation | December 1996 | January 1997 |

### Startup and Labor Issues

Upon startup, the company faced a number of hurdles. The initial production loss rate was about 35%—far above the 1-2% expected rate. Swindell Dressler found that the kiln’s cool-down zone was too short, causing products to crack from cooling too quickly. After they added a 20-foot extension at their expense, the kiln immediately achieved the projected production loss rate. Subsequently, Pacific Clay has experienced periodic higher-than-normal production loss rates, and additional fans are being installed to address the problem. Although the new kiln began operating before its target date, it actually began to fulfill project expectations by the original estimated startup date of January 1997.

Operating the new production line requires a more sophisticated labor force and a longer work week. Specifically, the LTM kiln needs four highly skilled crews of 7 people each to operate continuously, whereas two lesser-skilled crews of 35-40 people each operate one of Pacific Clay's existing kilns continuously. Further, the new crews required extensive training and were fully capable of operating the new plant after about 3 months. Finally, the brick production crews at the new plant must work seven days a week, instead of five days a week at the existing plants, increasing both labor and supervisory costs.

## Kiln Performance Comparison

The new kiln, TK-4, was expected to deliver dramatically improved performance compared to TK-2 and TK-3. The LTM kiln's performance improvements stem primarily from design differences compared to Pacific Clay's other kilns, as summarized in Table 3.

**Table 3: LTM Kiln Design Features and Performance Impacts**

| *Feature* | *Benefit* |
|---|---|
| • Ceramic fiber insulation in lieu of traditional refractory brick on the inside walls of the kiln | • Faster kiln heat-up after shutdown or turn-down |
| • Low-thermal-mass kiln cars | • Faster kiln heat-up after shutdown or turn-down |
| • Lower profile kiln cars | • Improved heat penetration info the center of the brick mass, cutting firing times |
| • Improved burner placement | • Improved heat circulation and reduced firing times |

Table 4 compares key performance indices of TK-2 and TK-4.

**Table 4: Comparison of Old and New Kiln Plants**

| *Characteristic* | | *TK-2* | *TK-4* | *TK-4 Improvement* |
|---|---|---|---|---|
| Production capacity | tons/year | 30,000 | 60,000 | 100% |
| Burner rating | $10^6$ Btu/hr | 29 | 25.9 | Na |
| Product height (on kiln car) | inches | 72 | 14 | Na |
| Production loss | % | 10 | 5 | 50% |
| Firing plus drying time[3] | hours | 96 | 48 | 50% |
| Preheat time (cold start) | hours | 96 | 24 | 75% |
| Natural gas consumption | therms/ton | 67.3 | 43.6 | 35% |
| Electricity consumption[4] | kWh/lb. brick | 0.0426 | 0.0448 | -5% |
| $NO_x$ emissions (oxidizing)[5] | lb/$10^6$ Btu gas<br>lb./ton brick | 0.056<br>0.377 | 0.062<br>0.270 | -11%<br>28% |

## Summary

Installing and operating the new kiln plant has been a challenging but worthwhile experience for Pacific Clay. However, addressing startup issues took longer than expected, delaying the achievement of all expected benefits.

[3] Exact duration depends on product requirements, with approximately 50% of the time for drying.
[4] "TK-4" is the 1999 plant average of TK-2, -3, and -4. "TK-2" is the 1995 plant average of TK-2 and -3.
[5] January 1999 test for TK-2; August 1997 test for TK-4.

# 3. Background

## *History*

Pacific Clay has been existence since the early 1900s, mining clay from the surrounding hills to produce bricks with colors unique in Southern California. The product line has changed since the plant's early days to meet the needs of the Los Angeles area as it developed over the years. At one time, the company's large pipe production plant supplied most of the sewer pipe for the Los Angeles metropolitan area. For quite a few years of late, Pacific Clay's product line has focused on an increasing variety of bricks used largely for paving in areas such as patios and swimming pool areas.

In addition to the plant's physical history, a recent part of its financial history is worth noting. The plant was privately held until 1975 when Pacific Holding Company was formed, an organization owned solely by David Murdock.

## *Plant Characteristics and Operation*

Using two 1950-vintage tunnel kilns, bricks are manufactured in a continuous process, similar to many brick plants across the country. Clay is ground, mixed and sifted to desired conditions, combined with water, extruded into required shapes, and cut into appropriate lengths.

After stacking products about six feet high on cars with high-refractory characteristics, the products enter a drying tunnel, bringing the moisture content down from about 20% to about 1% in about 48 hours. The drying tunnels heat products partly by using exhaust from the firing kilns and partly from an on-site cogeneration unit's[6] exhaust heat.

After drying, the product enters the firing kilns, which operate at about 1900–2300°F, depending on product type. Products are fired for about 48 hours, depending on product type. Kilns operate in either oxidizing or reducing mode, depending on product type. Most products are fired in an oxidizing environment.

Product handling is labor intensive for loading and unloading cars, as well as loading pallets. In many phases of the production line workers move and stack bricks individually.

Primarily because of the difficulty in getting uniform heat distribution throughout the large mass of product on each car in the firing kiln, variations in product quality require rejecting about 10% of the products fired. These rejected products are ground and mixed with raw clay for reprocessing.

[6] A 600-kW reciprocating engine supplies a large portion of the plant's electricity needs and a small portion of the drying heat requirements.

Depending on needs for production capacity, Pacific Clay may operate the plant continuously, 24 hours/day, 7 days/week, as it is doing in 1999. Production lines are designed to provide a 2.6-day reserve of unfired bricks. Therefore, during periods of continuous operation, the plant has adequate product-forming capacity to produce enough bricks in five days (a normal Monday through Friday work week) to enable the kilns to operate continuously, seven days a week. This allows the old plant to operate with only two brick-forming crews.

With lower production demands, as was the case during the early 1990s, well before the new kiln was proposed, operators would shut down kilns for weeks or even months at a time. Restarting a kiln requires about 4–5 days from a cold start, or 24 hours from an "idle" condition of 500°F to bring its entire thermal mass up to temperature. Such a long restart time makes short-term shutdowns impractical.

Table 5 summarizes characteristics of Pacific Clay's original tunnel kilns.

**Table 5: Existing Tunnel Kiln Characteristics**

| *Characteristic* | | *Tunnel Kiln #2 (TK-2)* | *Tunnel Kiln #3 (TK-3)* |
|---|---|---|---|
| Production capacity | tons/year | 30 | 30 |
| Burner rating | $10^6$ Btu/hr | 29 | 33.1 |
| Product height (on kiln cars) | inches | 72 | 72 |
| Firing plus drying time[7] | hours | 96 | 96 |
| Maintenance cost ($/yr.)[8] | $/year | 420,000 | 420,000 |
| Production losses[9] | % | 9 | 9 |
| Natural gas consumption[9] | therms/yr./lb. brick | 2000 | 2000 |
| Electricity consumption[9] | kWh/lb. brick | 0.0189 | 0.0189 |
| $NO_x$ emissions oxidizing/reducing[10] | lb/$10^6$ Btu gas | 0.056 / 0.070 | 0.082 / 0.073 |

## *Expansion Needed*

Over the years Pacific Clay upgraded the plant as needed to meet product demands and implement new technology. Tunnel kiln #1 (TK-1) was shut down years ago. An envelope kiln was added for specialty products such as large flower pots. TK-2 and TK-3 burners were upgraded for improved performance. Additionally, Pacific Clay

[7] Exact duration depends on product requirements, with approximately 50% of the time for drying.
[8] Average historical cost in 1992 and 1993. Costs for individual kilns not tracked separately; total cost assumed split equally between TK-2 and TK-3.
[9] Annual production average noted in Pacific Clay's 1/30/95 application to CEC.
[10] January 1999 test for TK-2; February 1997 test for TK-3.

management kept abreast of kiln design developments in the national and international markets.

During the early and mid-1990s, plant management decided to install a new production line with a new kiln to meet increased capacity needs and to reduce operating costs.

# 4. Expansion Plans and Expectations

## *New Kiln Selected*

To meet the growing needs for increased production, Pacific Clay conducted national and international research on alternative kiln designs in 1994 and 1995 and settled on a low-thermal-mass (LTM) kiln from Swindell Dressler, an American manufacturer. Interestingly, new kilns with older high-thermal-mass (HTM) technology used inTK-2 and TK-3 cost *more* than new LTM kilns, so this older technology was not a viable option for the new production line.

The new LTM kiln promised many valuable benefits over the older HTM kilns, including:

- Higher production capacity
- Improved product recovery rates (i.e. reduced breakage)
- Greater range of products available for firing
- Faster firing times
- Reduced $NO_X$ emissions
- Reduced labor cost
- Reduced maintenance cost
- Reduced energy cost

The LTM kiln's performance improvements stem primarily from design differences compared to Pacific Clay's other kilns, summarized in Table 6.

**Table 6: LTM Kiln Design Features and Performance Impacts**

| *Feature* | *Benefit* |
|---|---|
| • Ceramic fiber insulation in lieu of traditional refractory brick on the inside walls of the kiln | • Faster kiln heat-up after shutdown or turn-down |
| • Low-thermal-mass kiln cars | • Faster kiln heat-up after shutdown or turn-down |
| • Lower profile kiln cars | • Improved heat penetration info the center of the brick mass, cutting firing times |
| • Improved burner placement | • Improved heat circulation and reduced firing times |

This LTM kiln installation was Swindell Dressler's second installation in the world, the first being at a brick factory in Australia.

The new kiln, named TK-4 (tunnel kiln #4), would replace TK-2, although TK-2 would remain in place in case future production requirements necessitated its use. TK-4 would use existing clay grinding and mixing facilities, but would have a new integrated product manufacturing line (e.g. extruders), along with automated product-handling equipment. TK-4 and its associated manufacturing equipment would be housed in a new building.

## *Expected Performance Characteristics*

TK-4 was expected to deliver dramatically improved performance compared to TK-2 and TK-3. Table 7 summarizes key performance indices.

**Table 7: New Kiln Expected Performance vs. Existing Tunnel Kiln**

| *Characteristic* | | *TK-2* | *TK-4* | *TK-4 Improvement* |
|---|---|---|---|---|
| Production capacity | tons/year | 30 | 60 | 100% |
| Burner rating | $10^6$ Btu/hr | 29 | 25.9 | 11% |
| Product height (on kiln cars) | inches | 72 | 14 | na |
| Firing plus drying time[11] | hours | 96 | 48 | 50% |
| Maintenance cost[12] | $/year | 420,000 | 64,000 | 92% |
| Production loss[13] | % | 9 | 2 | 78% |
| Natural gas consumption [14] | therms/ton brick<br>Btu/lb. brick | 40<br>2000 | 19<br>950 | 52% |
| Water consumption | gallons/lb. brick | 0.024 | 0.022 | 8% |
| Electricity consumption | kWh/lb. brick[15] | 0.0189 | 0.0100 | 47% |
| $NO_X$ emissions[16] | lb. $NO_X/10^6$ Btu gas<br>lb. $NO_X/10^6$ $ft^3$ gas<br>lb. $NO_X$/ton brick | 0.203<br>213<br>0.974 | 0.081<br>85<br>0.154 | 60%<br><br>84% |

Electricity savings were expected from reduced firing time and less fan energy for air circulation (fewer and smaller fans, plus high-efficiency fan motors). Water savings were expected from increased product recovery.

[11] Exact length depends on product requirements, with approximately 50% of the time for drying.
[12] Average historical cost in 1992 and 1993. TK-3 cost not available and assumed similar to TK-2.
[13] 1994 production average.
[14] 1994 production average.
[15] 1994 production average.
[16] Data from 1996 report by Pilco.

Low-$NO_X$ "pulse" burners were considered as an option and were included in project plans when approaching potential project partners. Related $NO_X$-reducing measures included lower kiln-firing temperatures (2100°F vs. 2250°F); newer, higher velocity burners; and improved controls that would maintain all set points in the firing and cooling zones more accurately.

Approximately 91,000–182,000 gallons/year of water savings were also expected, based on reducing production loss rates from 10% to 1-2% for 60,000 tons/year production.

## Budget, Investment Criteria, and Funding

The total project budget was about $7.3 million, split approximately as shown in Table 8:

**Table 8: Project Budget**

| | |
|---|---|
| Kiln, including cars, site preparation, and construction | $3.2 Million |
| Associated production and handling equipment (e.g. extrusion) | $4.1 Million |
| *Total* | *$7.3 Million* |

Because of the need for expanded production capacity, Pacific Clay's investment was based on a business need, not a desire to reduce operating cost. Obviously, reduced operating cost was a tremendous benefit, but the financial analysis was not completed using return on investment (ROI), payback, or other investment analysis. Since the older technology was not a viable option, analysis comparing marginal impacts of new vs. old technology were not completed either.

The project was internally funded, since Pacific Clay's holding company had adequate funding.

## Expected Timeline

After selecting the kiln in 1995, work proceeded quickly. The expected timeline is summarized in Table 9.

**Table 9: Expected Project Timeline**

| | |
|---|---|
| Design and feasibility begins | July 1995 |
| Factory fabrication begins | January 1996 |
| Site grading and installing utilities begins | March 1996 |
| On-site construction begins | June 1996 |
| Construction complete | September 1996 |
| Unit fully operational | January 1997 |

## *Project Partners*

With such a high project cost and obvious environmental benefits, Pacific Clay sought funding assistance from organizations supporting such projects, including the local electric and gas utilities, the South Coast Air Quality Management District (SCAQMD), and the California Energy Commission (CEC). Only CEC had funding assistance available, through U.S. Department of Energy's NICE[3] program (National Industrial Competitiveness through Energy, Environment, and Economics). The program was established to help promote installation of advanced, energy saving industrial technologies.

Pacific Clay obtained commitment of $385,973.00 from CEC/DOE for installing the new kiln.

# 5. Construction and Startup

## *Overview*

In general the new kiln and production line's installation went fairly well. In fact, it came on-line in April 1996, long before the initially projected January 1997 date. However, there were several issues that increased the project cost and extended the date for proper plant operation.

## *Construction and Budget Issues*

Two major construction issues surfaced during the project. After grading began the county required Pacific Clay to raise the plant two feet and to improve the fire protection system. These changes added approximately $500,000 to the cost, bringing the final project cost to about $7.8 million.

The project as implemented saw one change from the initial plans. Low-$NO_X$ "pulse" burners were considered as an option, and were included in project plans when approaching potential project partners. However, they were not included in the project installation because they were not needed to obtain the AQMD operating permit.

## *TK-4 Startup Issues*

When the plant came on-line in April 1996 the production loss rate was 35%, far above the 1-2% expected. After much investigation, Swindell Dressler concluded the kiln's cool-down zone was too short, causing product cracking from cooling down too quickly. Swindell Dressler added, at their cost, a 20 foot kiln extension in December 1996 and then the plant immediately began to consistently have a 1-2% production loss rate.

During 1997 and 1998 Pacific Clay occasionally experienced a period of higher-than-normal production loss rates. After consulting with Swindell Dressler, they concluded that new fans are needed to improve heat distribution. This will be completed in the summer of 1999.

On a related note, since operating the new kiln Pacific Clay has had to establish new firing procedures for each of its many products.

## *Labor Issues*

Although not a huge problem, Pacific Clay quickly realized the new production line's sophisticated, automated equipment required a labor force more highly skilled than that required for TK-2 or -3. Additionally, the production line's design, with only a four-hour backlog capability, required continuous, full staffing and associated supervision to operate the kiln seven days a week. In effect, TK-4 requires four highly-skilled crews to operate continuously, while TK-3 requires two lesser-skilled crews to operate continuously. Although TK-4's crews have only 7 people compared to about 35-40 people (number depends on plant needs) to operate the TK-3 plant (about 50 people are required to operate TK-2 and TK-3 together), the TK-4 plant layout and design could be improved upon to further reduce labor cost.

### TK-2 Shut-Down Issues

The SCAQMD emissions permit to operate TK-4 stipulated that TK-2 be taken off-line to ensure that overall plant $NO_X$ emissions were not increased. Thus, when TK-4 came on-line in April, 1996, SCAQMD expected that TK-2 would no longer operate. However, since TK-4 did not operate *properly* when it came on-line, Pacific Clay argued that TK-2 should be allowed to operate until TK-4 was fully commissioned. After extensive negotiations, Pacific Clay shut down TK-2 in November, 1996, just before TK-4's startup problems were finally settled.

### Timeline

After deciding to move ahead with the project, Pacific Clay and its contractors were able to accelerate the project so it was on-line 10 months before the initial January 1997 date. However, startup problems took longer than expected to resolve, so the plant was not operating properly until December 1996, approximately the same time as expected.

**Table 10: Actual Project Timeline**

| *Activity* | *Actual Date* | *Projected Date* |
|---|---|---|
| Design and feasibility begins | July 1995 | July 1995 |
| Construction complete | April 1996 | September 1996 |
| Extend TK-4 | December 1996 | na |
| Proper TK-4 operation | December 1996 | January 1997 |

# 6. Results

## *Summary*

In brief, the new kiln and associated production equipment are working very well, and in the words of the company Vice President, "Yes, we'd definitely do it again!" Figure 3 and Figure 4 show the new plant and the range of Pacific Clay's production.

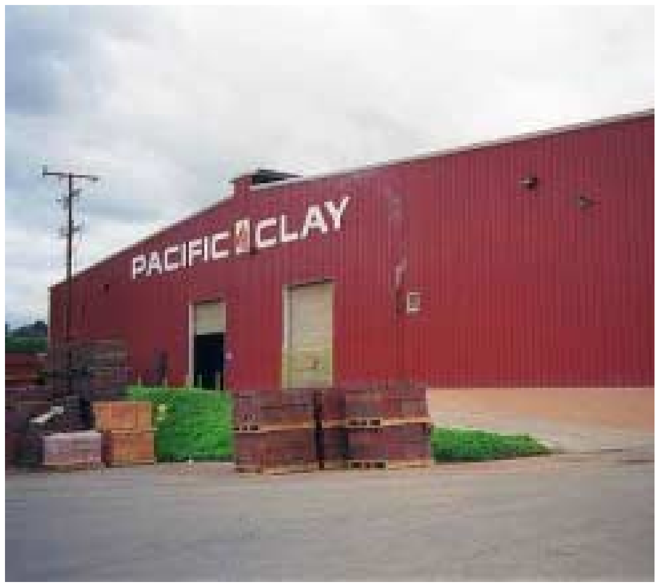


**Figure 3: New Kiln Plant**

**Figure 4: Range of Pacific Clay Brick Production**

## *The Bottom Line*

TK-4 is delivering many of the key benefits Pacific Clay expected to achieve when it installed the LTM kiln, most importantly improved product quality and increased production capacity. Pacific Clay is also enjoying reduced operating cost, although only about 50% of the expected gas savings; plant operators cannot identify the shortfall. A summary of benefits is listed below:

- Production capacity is up 100%
- Cycle time is cut 50%
- Production loss rate is down 50%
- Gas cost is cut 35%
- $NO_X$ emissions are cut 28%

Labor and maintenance savings have been smaller than expected, partly because new firing cycles must be established for new products, and startup problems have delayed achieving some benefits. Further, lack of detailed energy-use metering and corresponding records do not allow direct comparison of some characteristics. Water savings is negligible.

The reduced $NO_X$ emissions benefit Pacific Clay because the local AQMD enforces strict emission limits. Since TK-4 reduces $NO_X$ emissions by 20%, it extends Pacific Clay's "bank" of credits and defers the company's purchase of $NO_X$ credits on the open market.

Table 11 compares performance and operating characteristics of the old and new production plants. As noted above, current records do not allow direct comparison of several characteristics, including maintenance costs. These items are tracked for an entire kiln plant (TK-2/TK-3 or TK-4) or for the entire Pacific Clay facility. Thus Table 11 does not include the same comparison data as given in Table 7. Gas consumption data, in particular, is worth noting because the baseline TK-2 data shown in Table 7 is very low compared to current TK-2/TK-3 data in Table 11. We suspect the 1995 data in Table 7 is inaccurate.

See the Appendix for a more comprehensive data listing.

**Table 11: Comparison of Old and New Kilns**

| *Characteristic* | | *TK-4* | *TK-2* | *TK-4 Improvement* |
|---|---|---|---|---|
| Production capacity | Tons/year | 60,000 | 30,000 | 100% |
| Production loss rate | % | 5 | 8-13 | 50% |
| Firing plus drying time[17] | Hours | 48 | 96 | 50% |
| Natural gas consumption | Therms/ton | 43.6 | 67.3 | 35% |
| Maintenance cost ($/yr.)[18] | $/ton/year | 9.61 | 13.02 | 26% |
| Labor | hours | 0.99 | 1.3 | 23% |
| Electricity consumption[18] | kWh/lb. brick | 0.0448 | 0.0426 | -5% |
| $NO_x$ emissions (oxidizing)[19] | lb/$10^6$ Btu gas<br>lb./ton brick | 0.062<br>0.270 | 0.056<br>0.377 | -11%<br>28% |

Table 12 summarizes plant operating costs before and after installing the new kiln. Note, however, that the "before" and "after" TK-4 installation data does not isolate TK-4 because the costs are plant-wide averages.

**Table 12: Overall Plant Operating Cost Comparison[20]**

| *Cost Component* | *Pre-TK-4 $/ton* | *Post TK-4 $/ton* | *Savings w/TK-4* |
|---|---|---|---|
| Gas Cost | 17.51 | 11.34 | 35.2% |
| Electricity Cost | 7.76 | 8.17 | -5.3% |
| Labor Cost | 12.81 | 14.03 | -9.5% |
| Maintenance Cost | 13.02 | 9.61 | 26.2% |
| *Total* | *51.10* | *43.15* | *15.6%* |

One indication of the project's success is that Pacific Clay is considering an LTM kiln for their Yankee Hill Brick and Tile plant in Lincoln, Nebraska.

As the company Vice President, Allen Cunningham, said, "Installing this new kiln is like having children. While you're doing it you're not always sure its a good idea. But when you're done, you're glad you did it."

[17] Exact length depends on product requirements, with approximately 50% of the time for firing.
[18] "TK-4" is the 1999 plant average of TK-2, -3, and -4. "TK-2" is the 1995 plant average of TK-2 and -3.
[19] January, 1999 test for TK-2; August, 1997 test for TK-4.
[20] 1999 energy rates.

## *New Market Opportunities*

With reduced operating costs, Pacific Clay is more competitive in markets nationwide, including the East Coast, despite shipping costs.

Further, the LTM kiln's low stacking height has allowed Pacific Clay to increase the range of its production capability. Pacific Clay now manufactures successful new premium, high-value products—such as wall caps and a decorator line of terra cotta pots—that do not have the strength to be stacked six feet high, but can be fired in the low stack-height LTM kiln cars. These new products sell for about $237/ton, roughly 25% higher than Pacific Clay's basic product line.

## *Suggestions for Future Installations*

For companies considering LTM kiln installations, Pacific Clay recommends adopting a production layout that would use more kiln cars and associated kiln-car storage, thus providing a two-day backlog to cover weekend firing. TK-2 and TK-3 have this design and it would cut TK-4 labor costs by setting brick production on a five-day schedule and requiring only two crews rather than four crews as required by the existing plant design. (Firing would remain on a seven-day schedule.) Pacific Clay's Yankee Hill plant is considering this recommendation while evaluating kiln options.

## *Current Market Conditions*

Pacific Clay's LTM installation was slated to be Swindell Dressler's third installation of the advanced technology. However, the second plant was never installed so only two have operated worldwide. In early 1999 Swindell Dressler sold a third plant for installation at Thermal Ceramics Corporation, an insulating brick manufacturing plant in Georgia. This new plant is expected to come on-line in early 2000.

LTM kiln plant construction costs have increased since Pacific Clay's installation. Pacific Clay's vice president estimates that a similar-sized plant would now cost about $11 million, rather than their $7.8 million cost.

Swindell Dressler has changed the product name, now using "Low-Set" to describe the LTM kiln technology. A photo of this new kiln is given in Figure 5.

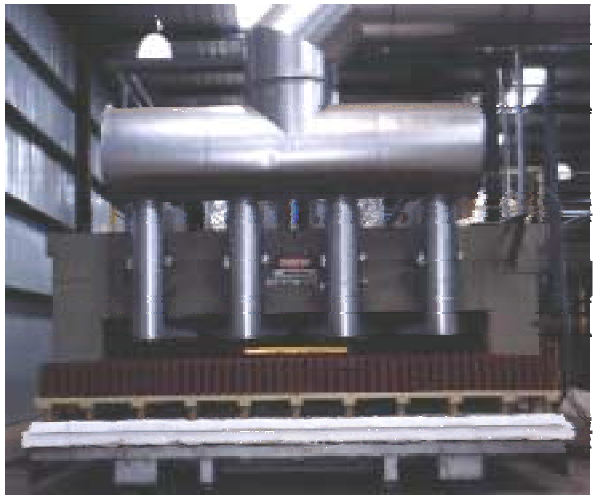

**Figure 5: Swindell Dressler Low-Set Kiln**

# 7. Potential California Applications

## *Best Applications*

As demonstrated at the Pacific Clay installation, good candidate sites for applying new LTM kiln technology are those facing a need for change where the new kiln can address this need. Table 13 summarizes characteristics of good candidate sites for LTM kiln technology.

**Table 13: Characteristics of Candidates for LTM Kiln Technology**

| *Characteristic* | *Observation* |
|---|---|
| Already needing to upgrade or expand production capacity | LTM technology has potential to cut gas costs 50%, but that’s not enough to justify shutting down an old kiln and adding a new kiln and associated production equipment |
| 7-day-a-week operation | High production volumes are required to justify the big investment |
| Facing emission requirements | LTM, especially with low-$NO_X$ burners, offers significant $NO_X$ reductions. |
| | Hydrogen fluoride is regulated in some European countries and LTM kilns cut these emissions as well |
| High gas costs | Energy savings are more valuable with high energy costs |

## *Candidate Companies*

The 1997 California Business Register database lists all California companies and categorizes them according to business type. Each company listing includes a range of characteristics, including site contacts and sales volume. We sorted the database to identify potential California sites for LTM kilns using the following SIC codes:

3251 – Brick and Structural Clay
3259 – Structural Clay Products, NEC
3296 – Mineral Wool
3297 – Non-clay Refractories
3431 – Enameled Iron and metal Sanitary Ware
3479 – Coating, Engraving, and Allied Services, NEC

This search listed 318 companies. A subsequent search of companies listing the above six SIC codes as their primary SIC listed 202 companies. After examining the results, we refined the search by looking only for companies listing the SIC codes 3251 and 3259, resulting in 19 companies. A review of those results eliminated three companies with business descriptions showing they would not use kilns to fire clay products. The remaining names are listed in Table 14. In addition, three names were supplied by the Pacific Clay Vice President. The database include one—Higgins Brick—and this is included in the table below. The database did not list two others—Castaic Brick and Atkinson Brick—but they are included below.

**Table 14: Candidate California LTM Kiln Sites**

| *Company* | *City* | *Executive Contact* | *Business Description* | *SIC codes* | *Sales Revenue Range* |
|---|---|---|---|---|---|
| Atkinson Brick | LA area | na | na | na | na |
| Bakersfield Sandstone Brick Co | Bakersfield | James Curran III 805-325-5722 | Brick and general building materials | 3251, 5211 | $10 to $24.9 Million |
| Barber-Webb Company Inc. | Los Angeles | Donald B Barber Jr 213-264-4800 | All types flexible membrane liners, fabricated and installed | 3089, 2899, 3259 | $5 to $9.99 Million |
| Boral Lifetile Inc.. | Newport Beach | Don Hinshaw 714-263-2780 | Manufactures roof tiles | 3251 | $100 to $499 Million |
| Castaic Brick | Castaic | David Freidman | na | na | na |
| Ceram-Tek | Corona | Timothy DiTomaso 909-278-2301 | Manufactures ceramic tile, marble and onyx spas | 3251, 3261, 3999 | Under $1 Million |
| Cla-Val Co | Dublin | Mike Landers 510-803-4646 | Manufactures clay valves | 3259 | Under $1 Million |
| Dal-Tile Corp | S San Francisco | Andrew Buonsante 415-873-8526 | Manufactures ceramic floor, wall tile; distributes ceramic tile and setting material | 5032, 3253, 3259 | Over $500 Million |

| *Company* | *City* | *Executive Contact* | *Business Description* | *SIC codes* | *Sales Revenue Range* |
|---|---|---|---|---|---|
| Atkinson Brick | LA area | na | na | na | na |
| | | | (sales office and warehouse) | | |
| Gladding McBean | Lincoln | William Padavona 916-645-3341 | Manufactures clay bricks, columns and poles | 3251, 3259 | $25 to $49.9 Million |
| H C Muddox Co | Sacramento | Dave Lucchetti 916-325-3620 | Manufactures and sells fired bricks | 3251, 5211 | $1 to $4.99 Million |
| Handcraft Tile Inc. | Milpitas | Clay J Scott 408-262-1140 | Manufactures handmade clay floor and wall tiles | 3253, 3259 | Under $1 Million |
| Hans Sumpf Co Inc.. | Madera | Tom Bryan 209-439-3214 | Manufactures adobe brick, ceramic murals, wall tile, sculpture and planters; restoration roof tile | 3269, 3251, 5032, 5211 | Under $1 Million |
| Higgins Brick Co | Los Angeles | Ronald Higgins 213-772-2813 | Manufactures brick and masonry cleaners and sealers | 2899, 3271 | $5 to $9.99 Million |
| Kohler Co | San Ramon | Kevin Moran 510-867-3211 | Simulates genuine masonry without bulk, weight or structural complications | 3259, 1799, 5032 | Over $500 Million |
| MCP Industries Inc. | Corona | Walter Garrett 909-736-1881 | Manufactures clay sewer pipes and rubber couplings; rubber injection molding | 3259, 3061 | $10 to $24.9 Million |
| Mission Clay Products Corp | Oakland | Owen Garret 510-568-0800 | Manufactures clay sewer pipe | 3259 | $1 to $4.99 Million |
| Pacific Clay Brick Products | Lake Elsinore | Dave Hollingsworth 909-674-2131 | Manufactures and sells brick and structural clay products | 3251, 5032, 5211 | $10 to $24.9 Million |
| United States Tile Co Inc. | Corona | Eric Hahn 909-737-0200 | Clay roofing tile | 3251 | $10 to $24.9 Million |
| Western Quarry Tile | Monrovia | Walter L Oleson 818-358-2465 | Manufactures structural clay products; ceramic tile for floors, counter tops and walls | 3259, 3253, 5211 | Under $1 Million |

# Appendix A: Technology Resource Information

## Technical Journals

- *Ceramic Industry;* Troy, MI, phone 248-362-3700
- *American Ceramic Society Bulletin*; www.acers.com, phone 614-890-4700
- *Ziegelindustrie International (Brick and Tile Industry International);* phone 49-6123-700-122

## Kiln Manufacturer

Swindell Dressler
P.O. Box 15541
Pittsburgh, PA 15244-0541
Telephone: 412-788-7100
Fax: 412-788-7110
E-mail: General Information: postmaster@swindelldressler.com
Sales: sales@swindelldressler.com
Web Site: www.swindelldressler.com

# Appendix B: Detailed Plant Performance Characteristics

*Product Notes:* Processed = raw material
Produced = raw product available for firing
Recovery = saleable product

*Data Notes:*
1995 baseline operation with TK2 and TK3
1998 annual data extrapolated from 2nd and 3rd quarter; 1st and 4th quarter had bad data (early-year TK4 extension and late-year kiln shutdown)
1999 five months and three weeks of data; TK2 came on-line 3/99

| **Characteristic** | | **1995** *TK2 & 3* | **1998** *TK3 & 4* | *TK3* | *TK4* | **Compare** *('98 TK4) / ('95 TK2/3)* | *Savings* | **1999** *TK2, 3 & 4* | *TK2 & 3* | *TK4* | **Compare** *('99 TK4) / ('95 TK2/3)* | *TK4 Benefit* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Production* | | | | | | | | | | | | |
| Processed | tons | 75,776 | 96,924 | 43,934 | 52,990 | | | 60,210 | 33,946 | 26,263 | | |
| Produced | tons | 68,411 | 82,840 | 35,148 | 47,692 | | | 50,794 | 27,157 | 23,637 | | |
| Recovery | tons | 63,147 | 71,634 | 31,340 | 40,034 | | | 46,013 | 23,542 | 22,471 | | |
| | | | | | | | | | | | | |
| *Energy Use* | | | | | | | | | | | | |
| Gas | therms | 4,252,383 | 4,088,046 | | | | | 2,565,317 | | | | |
| Elec, CES | kWh | 4,156,629 | 4,662,124 | | | | | 2,438,226 | | | | |
| Elec, SCE | kWh | 1,217,703 | 2,781,600 | | | | | 1,686,000 | | | | |
| | | | | | | | | | | | | |
| *Estimated Energy Cost* | | | | | | | | | | | | |
| Gas | $/therm | 0.21 | | | | | | 0.26 | | | | |
| yearly cost | | 893,000 | | | | | | 666,982 | | | | |
| cost @1999 rate | | 1,105,620 | | | | | | 666,982 | | | | |
| 1999 $/recovery ton | | 17.51 | | | | | | 14.50 | | | | |
| | | | | | | | | | | | | |
| Elec | $/kWh weighted => | 0.112 | | | | | | 0.091 | | | | |
| CES | | 58% | | | | | | 48% | | | | |
| SCE | | 42% | | | | | | 52% | | | | |
| yearly cost | | 601,925 | | | | | | 376,129 | | | | |
| cost @1999 rate | | 490,139 | | | | | | 376,129 | | | | |
| 1999 $/recovery ton | | 7.76 | | | | | | 8.17 | | | | |
| | | | | | | | | | | | | |
| *Labor* | | | | | | | | | | | | |
| Amount | hours | 81,408 | 129,598 | | | | | 76,920 | 54,739 | 22,181 | | |
| Cost | $ | 809,207 | 1,071,384 | | | | | 645,381 | | | | |
| | | | | | | | | | | | | |
| *Maintenance* | $ | 822,345 | 1,085,387 | | | | | 442,333 | | | | |
| | | | | | | | | | | | | |
| *Performance Indices* | | | | | | | | | | | | |
| Recovery | | | | | | | | | | | | |
| Produced/Processed | | 90.3% | 85.5% | 80.0% | 90.0% | 99.7% | | 84.4% | 80.0% | 90.0% | 99.7% | -0.3% |
| Recovery/Produced | | 92.3% | 86.5% | 89.2% | 83.9% | 90.9% | | 90.6% | 86.7% | 95.1% | 103.0% | 3.0% |
| Gas Energy | | | | | | | | | | | | |
| therms/"recovery ton" | | 67.3 | 57.1 | | | | | 55.8 | | | | |
| est therms/"recovery ton" | | | | 67.3 | 49.4 | 73.4% | | | 67.3 | 43.6 | 64.8% | 35.2% |
| est $/recovery ton, 1999 rate | | | | 17.51 | 12.84 | | | | 17.51 | 11.34 | | |
| | | | | | | | | | | | | |
| Elec Energy (kiln split est.) | | | | | | | | | | | | |
| kWh/"recovery ton" | | 85.1 | 103.9 | | | | | 89.6 | | | | |
| kWh/"recovery lb" | | 0.0426 | 0.0520 | | | | | 0.0448 | | | | |
| est kWh/"recovery ton" | | | | 85.1 | 119.3 | 140.2% | | | 85.1 | 94.4 | 110.9% | 10.9% |
| Labor | | | | | | | | | | | | |
| hr/"recovery ton" | | 1.29 | 1.81 | | | 1.40 | | 1.67 | 2.33 | 0.99 | 0.77 | |
| $/"recovery ton" | | 12.81 | - | | | - | | 14.03 | | | 1.09 | |
| Maintenance | | | | | | | | | | | | |
| $/recovery ton | | 13.02 | 15.15 | | | 1.16 | | 9.61 | | | 0.74 | |
| | | | | | | | | | | | | |
| NOx Emissions (1999 gas effic.) | | *oxidizing=>* | *TK-2* | *TK-3* | *TK-4* | *reducing ==>* | | *TK-2* | *TK-3* | *TK-4* | | |
| lb/MM Btu | | | 0.056 | 0.082 | 0.062 | | | 0.070 | 0.073 | 0.073 | | |
| lb/10^6 cubic ft | | | 58.7 | 85.9 | 64.9 | | | 73.3 | 76.5 | 76.5 | | |
| lb/therm | | | 0.0056 | 0.0082 | 0.0062 | | | 0.0070 | 0.0073 | 0.0073 | | |
| lb/recovery ton | | | 0.377 | 0.552 | 0.270 | | | 0.471 | 0.492 | 0.318 | | |